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NAVAL AIR ENGINEERING CENTER

REPORT NAEC-92-141

LAKEHURST, N.J.
08733

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ELECTRIC POWER QUALITY
TEST SET

Handling and Servicing/Armament Division
Ground Support Equipment Department
Naval Air Engineering Center
Lakehurst, New Jersey 08733

11 MARCH 1980

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Prepared for

Commander, Naval Air Systems Command
AIR-340E
Washington, DC 20361

NAEC-92-141

ELECTRIC POWER QUALITY TEST SET

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An analysis of the practicality and cost-effectiveness of a portable test set to determine compliance of an electric power system to MIL-STD-704C is undertaken. This is part of an overall effort to develop a new DOD Mobile Electric Power Plant (MEP-354). One of the main objectives of this program is to develop an electric power system capable of meeting the specifications of MIL-STD-704C.

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SUMMARY

A. GENERAL. The issuance of MIL-STD-704 and its subsequent revisions has guided electric power system designers and utilization equipment designers by providing for quality of power standards supplied to aircraft utilization equipment. A means to determine conformance of an electric power system to MIL-STD-704C is considered. This report documents the results of a study to determine the feasibility and practicality of developing a portable test set to determine conformance of an electric power system to MIL-STD-704C for use by organizational and intermediate maintenance level personnel.

B. PROCEDURES AND RESULTS. An analysis was undertaken to determine the pros and cons of developing a portable test set to determine conformance of an electric power system to MIL-STD-704C. The analysis was a result of contacts made with personnel ranging from aircraft maintenance personnel to experts in the area of electric power generation. Results from this analysis indicate it is not practical to develop a test set at this time to measure the full range of characteristics of MIL-STD-704C to determine conformance of an AC or DC electric power system to MIL-STD-704C.

C. CONCLUSIONS AND RECOMMENDATIONS. The main conclusion of the analysis undertaken is that it is neither practical nor cost effective to develop a portable test set to determine conformance of an electric power system to MIL-STD-704C. It is recommended that further study be undertaken to determine the actual quality of power of existing aircraft electric power systems and the effects, both short-term and long-term, of nonqualified power on utilization equipment. From these studies it may be possible to affect a revision to MIL-STD-704 and at that time to determine the advisability of pursuing development of a test set.

PREFACE

Increased attention has been focused on the quality of power supplied to aircraft utilization equipment by the aircraft electric power system and by external electric power sources. MIL-STD-704C establishes requirements for electric power characteristics on aircraft at the interface between the electric power system and the input to electric utilization equipment. A single instrument to determine compliance of electric power characteristics to MIL-STD-704C does not exist. An analysis is undertaken to consider the advisability of developing a portable test set to determine compliance of electric power systems to MIL-STD-704C.

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I. INTRODUCTION

On 6 October 1959, MIL-STD-704 was issued. Reference (a) documents the development of MIL-STD-704. Basically MIL-STD-704 establishes requirements for electric power characteristics on aircraft at the interface between the electric power system and the input to electric utilization equipment. This standard affects aircraft electric power systems as well as external power systems used for powering aircraft while on the ground. MIL-STD-704 replaced MIL-E-7894 which was originally developed in order that the electric power system designer would know what power characteristics he must supply without any knowledge of the connected load, and the utilization equipment designer would know what power he must use without any knowledge of the actual power source, each knowing his responsibilities in his areas. MIL-STD-704 replaced MIL-E-7894 to remove the deficiencies and problems which minimized the usefulness of MIL-E-7894 and caused it to be replaced in many cases by versions prepared by airframe companies for use with military aircraft.

Since its introduction in October 1959, MIL-STD-704 has been revised three times. The latest revision, MIL-STD-704C,was issued 30 December 1977.

In 1975 four programs were initiated in the 6.2 RDT&E area to support development of a new Mobile Electric Power Plant (MEPP), MEP-354. One program was concerned with the drive system to be included in the new MEPP. Two of the programs were concerned with developing an electrical power system to meet the requirements of MIL-STD-704C. The fourth program was initiated to develop a test set to determine compliance of the electric power system to MIL-STD-704C. The intent at the initiation of the program was to develop a test set for use at the organizational and intermediate maintenance levels to determine compliance of a MEPP or aircraft electric system to MIL-STD-704C.

II. BACKGROUND

Reference (a) documents the development of MIL-STD-704. "Electrical Power, Aircraft, Characteristics and Utilization of." MIL-STD-704 was prepared to define the characteristics of aircraft electric power at the terminals of the utilization equipment. From this specification the electric power system designer knows what power characteristics he must supply without any knowledge of the connected load, and the utilization equipment designer knows what power he must use without any knowledge of the actual power source, each knowing his responsibilities in his areas.

In 1966 MIL-STD-704A superseded MIL-STD-704. MIL-STD-704B superseded MIL-STD-704A in November 1975, which was superseded by MIL-STD-704C in December 1977.

The essence of MIL-STD-704 is that it defines the quality of electric power which must be supplied to utilization equipment within an aircraft. The revisions to MIL-STD-704 through the years are due in part to changes in both electric power systems and utilization equipment.

Ref: (a) Naval Air Development Center Report No. NADC-EL-6029 of 9 August 1960: Final Report - Engineering Investigations in the Development of MIL-STD-704 to Replace Specification No. MIL-E-7894.

In 1975 the Naval Air Engineering Center initiated work in the 6.2 RDT&E area to develop a new 30KW Mobile Electric Power Plant (MEPP), MEP-354. The largest portion of this work was to develop an AC electric power generating system capable of meeting the requirements of MIL-STD-704C. In addition, a program was initiated to develop a portable test set for organizational and intermediate level maintenance capable of determining compliance of a MEPP's electric output to MIL-STD-704C. It was also intended to be able to determine compliance of an aircraft's internal electric power system to MIL-STD-704C or any ground power source with the same equipment.

At the time of initiation of work on MEP-354, there was no single portable instrument capable of determining conformance to MIL-STD-704C. At the present time there is still no such instrument available. There are many single portable instruments capable of measuring one or more of the electric characteristics which are defined in MIL-STD-704C. An example of such an instrument is the Electrical Circuit Test Set - AN/USM-128 which is a multi-range, portable unit capable of measuring DC voltages, AC voltages, frequency and phasing sequence of three-phase, four-wire and three-phase, three-wire inputs of certain power generating units.

III. ANALYSIS

Reference (b) recommended that a test set be developed for use by organizational and intermediate maintenance level personnel in order to determine compliance of electric power generating systems to MIL-STD-704C. The intended test set was to include capability for checking aircraft electric systems as well as MEPP's and any other source of ground electric power. Since the release of reference (b), however, various Navy personnel, airframe and generator contractors have questioned the plan of action to develop such a test set and have questioned its intended use.

MIL-STD-704C, the latest version of MIL-STD-704, was issued in December 1977. From contacts made in the field, it is evident that there is much dissatisfaction with this latest revision. There is support for another revision to MIL-STD-704.

One of the recommendations of reference (b) is to develop a test set which could indicate to a relatively unsophisticated user conformance to MIL-STD-704C on a go/no go basis with an indication for each characteristic of electrical power (voltage, frequency, phase balance, harmonic distortion etc.) with limits for each parameter stored in firmware. Anytime a revision to MIL-STD-704 is made it is likely that a change to such a test set could be made through a change in firmware. This would necessitate sending new memory chips to users to replace existing memory chips. This is one problem but not in itself an insurmountable problem.

Ref: (b) Naval Air Engineering Center Report No. NAEC-GSED-103 of 19 May 1977: Mobile Electric Power Plant (MEPP) Test Set Development.

Another approach is to develop a test set which indicates measured electric characteristics on a quantitative rather than qualitative basis. The drawback of this approach is the inability of the intended user to interpret readings due to the low level of training and experience. Voltage and frequency readings in an AC electric system are easily interpreted. It is trivial to determine if an aircraft or MEPP electric system's steady-state voltage and frequency levels are within MIL-STD-704C limits. However, other characteristics such as waveform distortion factor, waveform distortion spectrum, crest factor, frequency deviation and frequency drift rate are not easily interpreted or understood.

The AN/USM-128 Electrical Circuitry Test Set is available to measure DC voltages, AC voltages, frequency and phasing sequence. There is ample documentation concerning the effects which out-of-limit steady-state voltage and frequency levels have on utilization equipment. Most of the problems being experienced today in the Fleet due to faulty power can be attributed to high 400 HZ voltage applied to aircraft from external electric power sources including mobile electric power plants and fixed installations. More research into the effects of other characteristics of electric power other than steady-state voltage and frequency is needed. This will serve a twofold purpose: (1) it will serve as a basis for further revisions of MIL-STD-704C, and (2) it will serve as a basis for the need for a test set at the organizational and intermediate levels to determine compliance of all characteristics of an electric power system to such a revision.

If a test set were to be developed for use at the organizational and intermediate levels of maintenance, one must determine what action must be taken if a MEPP's or an aircraft's electric system was out of compliance with MIL-STD-704C. We shall first determine the case of the MEPP. If it is determined that a MEPP's voltage or frequency levels are out of limits, it is a relatively simple process to make adjustments at the intermediate level of maintenance to bring voltage and frequency levels within limits. If on the other hand, another characteristic of MIL-STD-704C is found to be out of limits, it is not a simple task to affect a change. At the very least the unit would be sent to the depot level for rework. Characteristics such as waveform distortion factor, waveform distortion spectrum, crest factor, etc., are fixed for fixed loads at the time of manufacture of the electric generator. These inherent characteristics should be checked during acceptance tests for the MEPP. Little can be done short of complete overhaul of the MEPP's generator to affect changes in these characteristics. Another question must be raised as to what effects characteristics other than steady-state voltage and frequency have on the performance and life of utilization equipment especially those characteristics which are not in accordance with MIL-STD-704C.

If a test set were to be utilized to determine if an aircraft's electric system was in accordance with MIL-STD-704C, another set of problems arises. Assume that the aircraft's generators are running on the ground powered by the aircraft's main engines and that various aircraft loads are applied. Also assume that electric power is being monitored at one point on the aircraft. If voltage and/or frequency levels are out of limits, adjustments may be made on the aircraft to bring these characteristics within limits at the point where power is being monitored. However, this does not guarantee that that voltage levels at other points in the aircraft will be within limits. Also if other characteristics such as the harmonic distortion spectrum are not within limits, it may be due not only to the aircraft electric generator but also to the utilization equipment. Utilization equipment may employ switching power supplies which often play havoc with an electric power system by introducing undesirable harmonic distortion. This is but one example but it points out the difficulty in isolating the cause of out-of-limit electric characteristics. It is also difficult to assess the impact of out-of-limit characteristics other than steady-state voltage and frequency on utilization equipment.

A portable test set to determine conformance of an electrical power system to MIL-STD-704C could possibly be utilized by a relatively small group of experts to isolate troublesome loads on an aircraft and to conduct research into the effects of all electric power characteristics on utilization equipment. As was stated before, it could also serve as a tool for future revisions to MIL-STD-704. The preceding discussion also demonstrates that such a test set would be impractical for the average maintenance person at the organizational or intermediate levels.

MIL-STD-704C establishes requirements for electric power on aircraft at the interface between the electric power system and the input to electric utilization equipment. In order to determine absolute compliance with MIL-STD-704C, it is necessary to determine conformance at the inputs to each piece of utilization equipment on the aircraft. This requires a mating connector for each piece of utilization equipment on the aircraft. However, analysis indicates it is possible to check conformance at approximately six points on the aircraft to determine total conformance. This also presents a tremendous problem in that approximately six connectors for each model aircraft would have to be made available to check aircraft electric power characteristics for conformance to MIL-STD-704C. This would create an enormous logistics problem to supply six connectors per aircraft model for use with the test set. In addition, the time necessary to prepare the aircraft for testing could be prohibitive, especially at the organizational level.

There are a few other considerations to be made which have somewhat of a bearing on the need for a test set. NAVAIRENGCEN is presently developing a new 30KW MEPP (MEP-354). MEP-354 will replace existing NC-8A and NC-2A MEPP's. It is intended to incorporate self-testing features within MEP-354 so that if steady-state voltage or frequency levels should drift out of limits of MIL-STD-704C, the load will be automatically disconnected.

The load will not be able to be reconnected until the generator output is within the proper limits. In addition there will be no external adjustments for voltage and frequency on the MEPP. This will serve to solve some of the problems which are presently being experienced in the field where external power sources with out-of-limit voltage and frequency levels are being applied to aircraft causing utilization equipment failures. In addition many aircraft such as A-6, A-7, F-14, H-2, H-53, P-3, and S-3 employ external power monitors to prevent application of faulty external power. These monitors automatically disconnect external power if voltage or frequency levels are out of limits. However, reports have been received of monitors being bypassed when aircraft would not accept external power. This is not an approved practice and must be discontinued.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. It is not advisable to develop a portable test set to determine conformance of all electric characteristics to MIL-STD-704C for use at the organizational or intermediate levels of maintenance at this time.

2. An intensive study of present aircraft electric system characteristics and their effects upon utilization equipment is needed prior to development of a portable test set to determine conformance of all electric characteristics to MIL-STD-704C.

3. Further research into the present revision of MIL-STD-704 is required.

B. RECOMMENDATIONS

1. A study of present aircraft electric system characteristics (AC and DC systems) should be initiated to determine the existent aircraft quality of power over a wide range of aircraft. It is also desirable to plot failure rates of utilization equipment versus quality of power (internal or external). This information may then be utilized to assess the need for a portable test set to determine compliance of all electric power system characteristics to MIL-STD-704C.

2. The present revision of MIL-STD-704 should be further investigated for improvements in suitability. This may be accomplished during a conference attended by all those concerned with this specification.

3. An engineering development effort should be initiated to investigate improvements in the AN/USM-128 Electrical Circuitry Test Set. Substitution of a digital meter for the existing analog meter to improve resolution is one of the recommendations for improvements.

4. The development of a portable test set to determine conformance of all electric power system characteristics to MIL-STD-704C should not be pursued at this time.

MIL-STD-704C
30 DECEMBER 1977
SUPERSESSION DATA
(SEE 6.1)

MILITARY STANDARD

AIRCRAFT ELECTRIC POWER CHARACTERISTICS

FSC MISC

DEPARTMENT OF DEFENSE
Washington, DC 20301

AIRCRAFT ELECTRIC POWER CHARACTERISTICS

MIL-STD-704C

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commanding Officer, Engineering Specifications and Standards Department (Code 93), Naval Air Engineering Center, Lakehurst, New Jersey 08733 by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

This standard establishes requirements for electric power characteristics on aircraft at the interface between the electric power system and the input to electric utilization equipment. The electric power characteristics covered by this standard are of duration longer than 50 microseconds or frequencies less than 20 kilohertz. Electric power characteristics of less than 50 microseconds or frequencies greater than 20 kilohertz are covered by the Military Specification for Electromagnetic Compatibility Requirements, Systems (MIL-E-6051).

2. REFERENCED DOCUMENTS

2.1 The issues of the following documents in effect on date of invitation for bids, form a part of this standard to the extent specified herein.

SPECIFICATIONS

Military

MIL-E-6051	Electromagnetic Compatibility Requirements, Systems

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specific procurement functions should be obtained from the procuring activity or as directed by the Contracting Officer.)

STANDARDS

Industry

IEEE STD-100-1972	IEEE Standard Dictionary of Electrical and Electronic Terms

2.1.1 Addresses for documents referenced herein, not obtainable from the Government, are as follows:

IEEE	Institute of Electrical & Electronics Engineers, Incorporated 345 East 47th Street New York, New York 10017

3. DEFINITIONS

3.1 Definitions of terms not explicitly treated are as given by IEEE Standard Dictionary of Electrical and Electronic Terms.

3.2 AC voltage. The term ac voltage refers to the gross, root mean square (rms) phase to neutral value unless otherwise designated.

3.3 Crest factor. The crest factor of the ac voltage waveform is defined as the ratio of the peak to rms value.

3.4 Distortion. AC distortion is the rms value of the ac waveform exclusive of the fundamental. AC distortion includes the components resulting from amplitude modulation as well as harmonic and non-harmonic components. In a dc system, distortion is the rms of the superimposed alternating voltage.

3.4.1 Distortion factor. The ac distortion factor is the ratio of the ac distortion to the rms value of the fundamental component. The dc distortion factor is the ratio of the dc distortion to the average dc voltage.

3.4.2 Distortion spectrum. The distortion spectrum quantifies ac distortion and dc distortion in terms of the amplitude of each frequency component. The distortion spectrum includes the components resulting from amplitude and frequency modulation as well as harmonic and non-harmonic components of the ac waveform.

3.5 Emergency operation. The emergency operation is that condition of the electric system whereby a limited electric source, independent of the main generation equipment, is used to power a selected, reduced complement of distribution and utilization equipment.

3.6 Frequency. Frequency is equal to the reciprocal of the alternation period of the fundamental of the ac voltage. The unit of frequency is the number of alternations per second of the ac voltage and is designated hertz (Hz).

3.6.1 Nominal frequency. The nominal frequency is 400 Hz.

3.6.2 Frequency drift. Frequency drift is the slow and random variation of the controlled frequency level within steady state limits due to such influences as environmental effects and aging.

3.6.2.1 Frequency drift rate. The frequency drift rate is the time rate of frequency change due to frequency drift.

3.6.3 Frequency deviation. Frequency deviation is defined as difference between maximum and minimum values of 1/T, where T is the period of one cycle of the fundamental of the phase voltage. The rate at which 1/T values repeat cyclically is called the rate of frequency change.

3.6.4 Frequency transient. The frequency transient is the locus of values defined by the reciprocals of sequential alternation periods of the ac voltage, in instances when the frequency departs from the steady-state value.

3.7 Overvoltage and undervoltage. Overvoltage and undervoltage are those voltages which exceed the combined steady state and transient limits and are terminated by the action of protective devices.

3.8 Protected operation. The protected operation is that condition of the electric system wherein a malfunction or failure in the electric system has taken place and the protective devices of the electric system are operating to remove the malfunction or failure from the remainder of the system.

3.9 Ripple amplitude. The ripple amplitude is the maximum value of the difference between the average and the instantaneous values of a pulsating unidirectional wave. (See 2.1, IEEE Standard.)

3.10 Starting operation. The starting operation is that condition of the electric system during starting of the aircraft propulsion engines.

3.11 Steady state. A steady state condition of the characteristics is one in which the characteristic shows only negligible change throughout an arbitrarily long period of time.

3.12 Transfer operation. The transfer operation is that condition of the electric system which takes place when a transfer is taking place between power sources, including transfers from or to external power sources.

3.13 Utilization equipment. Utilization equipment is that which receives power from the electric power system.

3.13.1 Utilization equipment terminals. Utilization equipment terminals are the terminals through which the electric power system is connected to the utilization equipment. Power interconnections within the utilization equipment or equipment system are excluded.

3.14 Voltage phase difference. The voltage phase difference is the difference in electrical degrees between the fundamental components of any two phase voltages taken at consecutive zero or dc level crossings of their instantaneous values traced in the negative to positive direction.

3.15 Voltage unbalance. Voltage unbalance is defined as the maximum difference among phase voltage magnitudes at the utilization equipment terminals.

4. GENERAL REQUIREMENTS

4.1 Aircraft power system requirements.

4.1.1 Power system performance. The aircraft electric power system shall present the electric power characteristics as specified in this standard at the power input connections of the aircraft electric utilization equipment during all operations of the power system including operations from externally supplied power sources.

4.1.2 Emergency and starting performance disconnect. During aircraft emergency or starting operations the aircraft electric power system shall automatically disconnect all utilization equipment whose specifications do not include requirements for emergency or starting performance, unless the aircraft electric power system provides the full performance characteristics specified herein during the aircraft emergency or starting conditions.

4.2 Aircraft utilization equipment requirements.

4.2.1 Full performance. When supplied electric power characteristics as stated herein for full performance, each utilization equipment shall provide the full performance required by its specification.

4.2.2 Protected and transfer performance. When supplied electric power characteristics as stated herein for protected or transfer performance, each utilization equipment:

a. shall be permitted a degradation or loss of function unless required by its specification, and

b. shall not produce a damaging or unsafe condition, and

c. shall automatically recover full specified performance when the electric power characteristics are restored to the full performance limits herein.

4.2.3 Emergency and starting performance. When the detail specification for the utilization equipment requires operation during emergency or starting conditions, then the utilization equipment shall provide the full performance required by its detail specification when supplied electric power characteristics as stated herein for emergency or starting performance.

4.2.4 Partial power failure. The failure of one or more phases of ac power or the loss of power to any input terminals of equipment which require ac and dc power shall not result in an unsafe condition.

4.2.5 AC phase power utilization. Loads greater than 0.5 KVA utilizing ac power shall be configured to utilize 3 phase steady state balanced power within the limits of Figure 1. Single phase power shall be used only on a line-to-neutral basis.

5. DETAIL REQUIREMENTS

5.1 Transfer performance characteristics. Under conditions of bus or power source transfers, voltage shall be between zero volts and full performance characteristics for no longer than 50 milliseconds.

5.2 AC power characteristics.

5.2.1 Type system. AC power characteristics are those of a single-phase or three-phase wye-connected neutral or ground return system having a nominal voltage of 115/200 volts and a nominal frequency of 400 Hz. The only alternate standard is a nominal 230/400 volts when specifically authorized. The voltage magnitude limits for the 115/200 volts standard shall apply proprotionally to the 230/400 volts standard. The power characteristics specified herein can take place on each phase independent of other phases unless otherwise stated.

5.2.2 Phase sequence. The phase sequence shall be A-B-C corresponding to aircraft wire designations, see Figure 2.

5.2.3 AC full performance characteristics.

5.2.3.1 AC steady state characteristics. The ac steady state characteristics shall be in accordance with Table I.

5.2.3.2 AC transient characteristics.

5.2.3.2.1 AC voltage transients. The ac voltage transients shall be within the limits of Figure 5.

5.2.3.2.2 AC frequency transient.

5.2.3.2.2.1 Transient limits. The ac frequency transients shall be within the limits of Figure 6.

5.2.3.2.2.2 Frequency change rate. The rate of frequency change shall not exceed 500 Hz/seconds for any period greater than 15 milliseconds.

5.2.4 AC protected performance characteristics.

5.2.4.1 AC overvoltage and undervoltage. The ac overvoltage and undervoltage values shall be within the limits of Figure 7.

5.2.4.2 AC overfrequency and underfrequency. The ac overfrequency and underfrequency values shall be within the limits of Figure 8.

5.2.5 AC emergency or starting performance. All electric power characteristics in ac emergency or starting operations shall be the same as for full performance except for steady state voltage and steady state frequency.

5.2.5.1 AC emergency or starting steady state voltage. The ac steady state voltage in the emergency or starting operation shall be within 104 to 122 volts.

5.2.5.2 AC emergency or starting steady state frequency. The ac steady state frequency in the emergency or starting operations shall be within 360 to 440 hertz.

5.3 DC power characteristics.

5.3.1 Type system. DC power characteristics are those of a direct current, two-wire or ground return system having a nominal voltage of 28 volts. The only alternate standard is a nominal 270 volts when specifically authorized.

5.3.2 DC full performance characteristics. The dc full performance characteristics shall be in accordance with Table II.

5.3.3 DC protected performance characteristics.

5.3.3.1 28 volts system. The dc overvoltage and undervoltage values for the 28 volts (nominal) system shall be within the limits of Figure 12.

5.3.3.2 270 volts system. The dc overvoltage and undervoltage values for the 270 volts (nominal) system shall be within the limits of Figure 13.

5.3.4 DC emergency or starting steady state voltage.

5.3.4.1 28 volts (nominal) system. The dc steady state voltage in the emergency or starting operation shall be within 16.0 to 30.0 volts.

5.3.4.2 270 volts (nominal) system. The dc steady state voltage in the emergency or starting operation shall be within 240 to 290 volts.

6. NOTES

The material in this section is not a mandatory part of this standard.

6.1 Supersession data. MIL-STD-704C supersedes MIL-STD-704B dated 17 November 1975, for new system designs. MIL-STD-704A and MIL-STD-704B may be used for existing systems applications or reordered equipment. Users of MIL-STD-704 are reminded that existing applications may require a continued use of MIL-STD-704A dated 9 August 1966, and MIL-STD-704B dated 17 November 1975. MIL-STD-704A and MIL-STD-704B issue with its associated amendments should be retained.

6.2 International Standardization Agreement. Certain provisions of this standard are subject to international standardization agreements: NATO STANAG 3456, NATO STANAG 3516, ASCC Air Standard 12/10, and Air Standard 12/19. When amendment, revision or cancellation of this standard is proposed, that will affect or violate the international agreement concerned, the preparing activity will take appropriate reconciliation action through international standardization channels, including departmental offices, if required.

6.3 Changes from the previous issue. Asterisks are normally used to identify changes from the previous issue of a Military document. Because of the extensiveness of this revision, this practice has not been followed in this issue.

Custodians:
Army - AV
Navy - AS
Air Force - 11

Preparing activity:
Navy - AS
(Project No. MISC-0B91)

Table I.

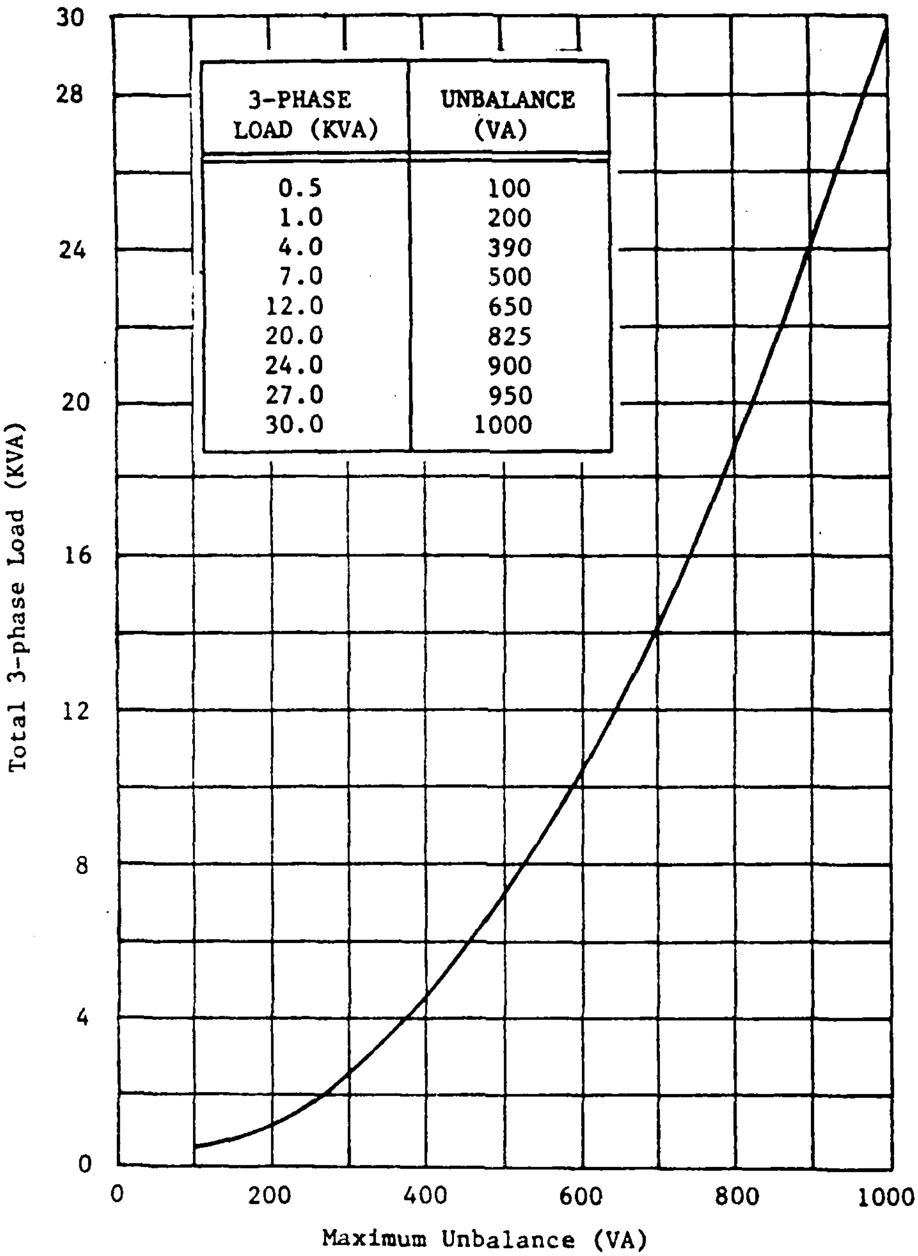
AC Steady State Characteristics (See 5.2.3.1)

Characteristics	Limits
Voltage	108.0 to 118.0 volts
Voltage unbalance	3 volts maximum
Voltage phase difference	116° to 124°
Waveform distortion factor	0.05 maximum
Waveform distortion spectrum	Figure 3
Crest factor	1.31 to 1.51
DC component	+0.10 to -0.10 volts
Frequency	393 to 407 hertz
Frequency deviation	Figure 4
Frequency drift rate	15 hertz per minute maximum

Table II.

DC Full Performance Characteristics (See 5.3.2)

Characteristic	Limits	
	28 volts (nominal) system	270 volts (nominal) system
Steady state voltage	22.0 to 29.0 volts	250 to 280 volts
Distortion factor	0.035 maximum	• 0.008 maximum
Distortion spectrum	Figure 9	Figure 9
Ripple amplitude	1.5 volts maximum	6.0 volts maximum
Voltage transient	Figure 10	Figure 11



3-PHASE LOAD (KVA)	UNBALANCE (VA)
0.5	100
1.0	200
4.0	390
7.0	500
12.0	650
20.0	825
24.0	900
27.0	950
30.0	1000

Figure 1. Unbalance Limits for 3-Phase Utilization Equipment (See 4.2.5)

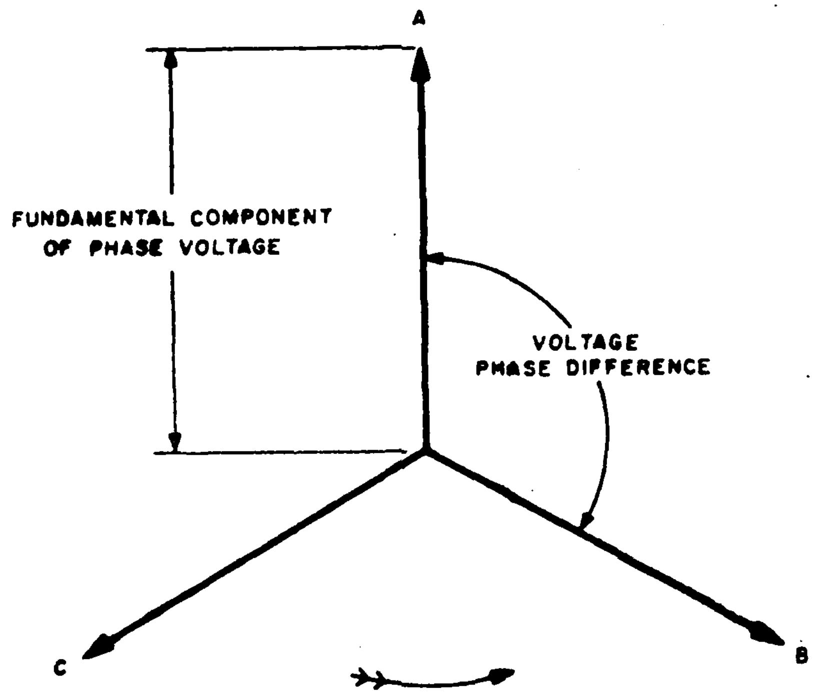


Figure 2. Phasor Diagram Showing Required Phase Sequence Relationship (See 5.2.2)

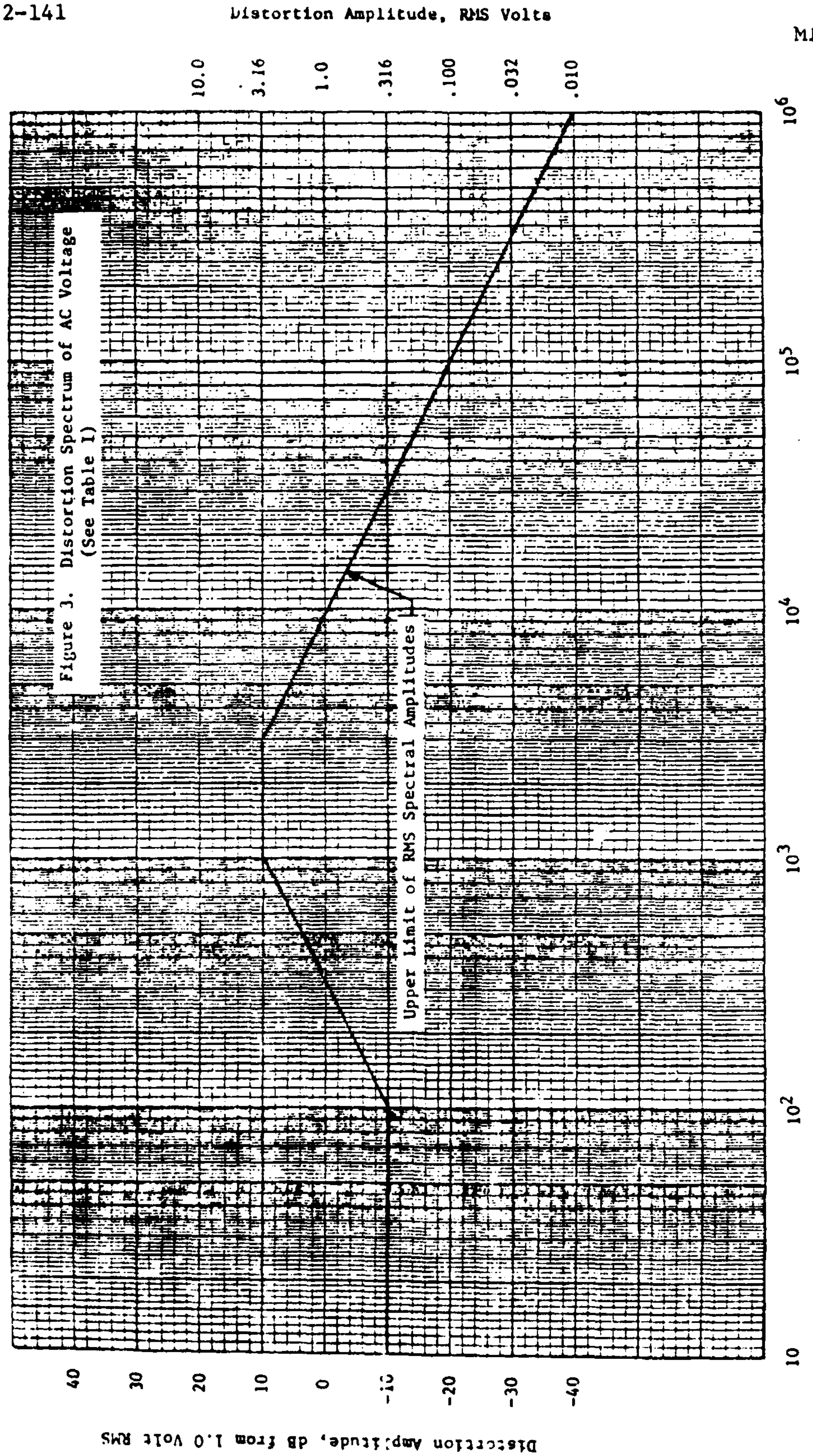


Figure 3. Distortion Spectrum of AC Voltage (See Table I)

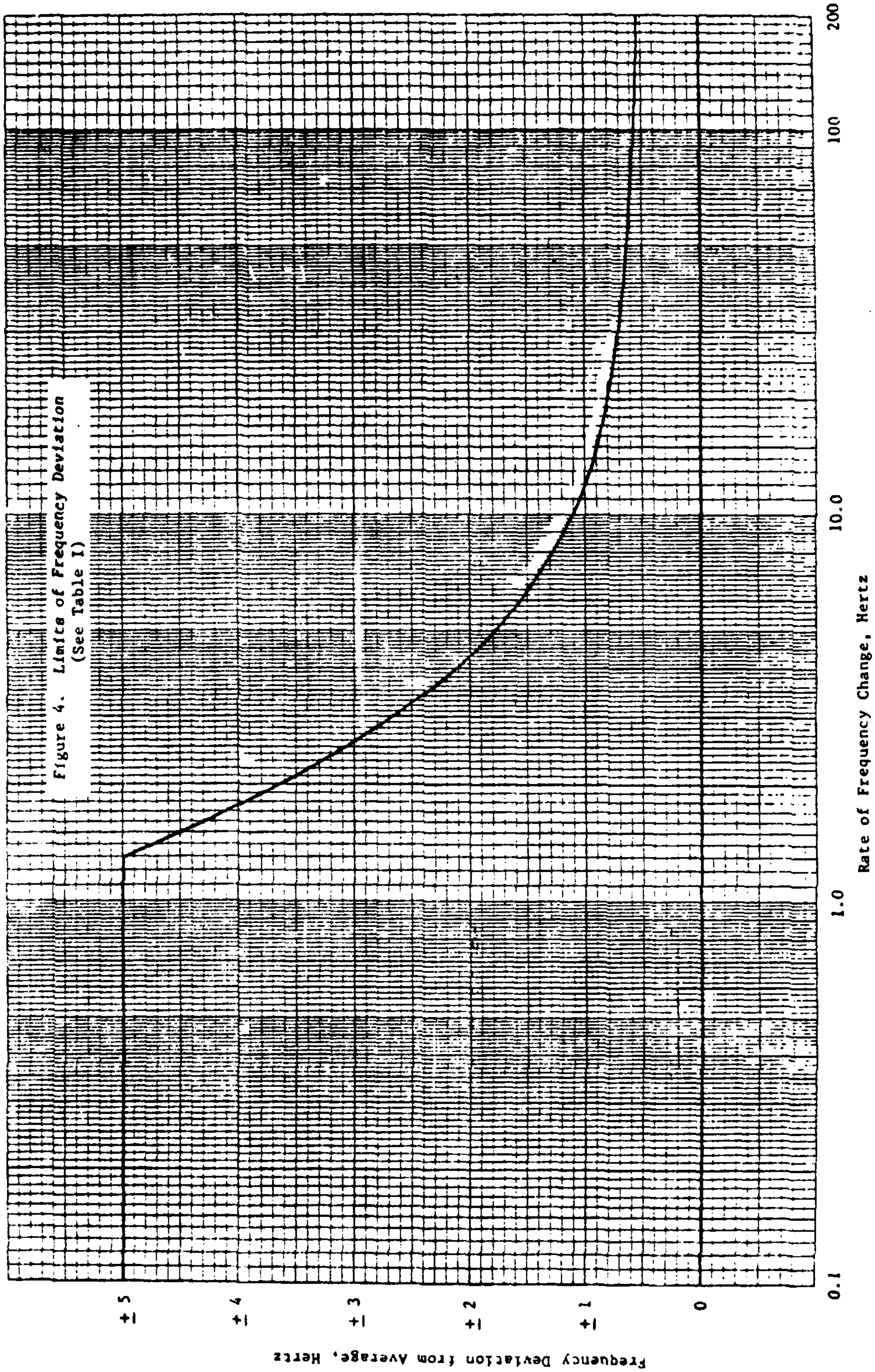


Figure 4. *Limits of Frequency Deviation*
(See Table I)

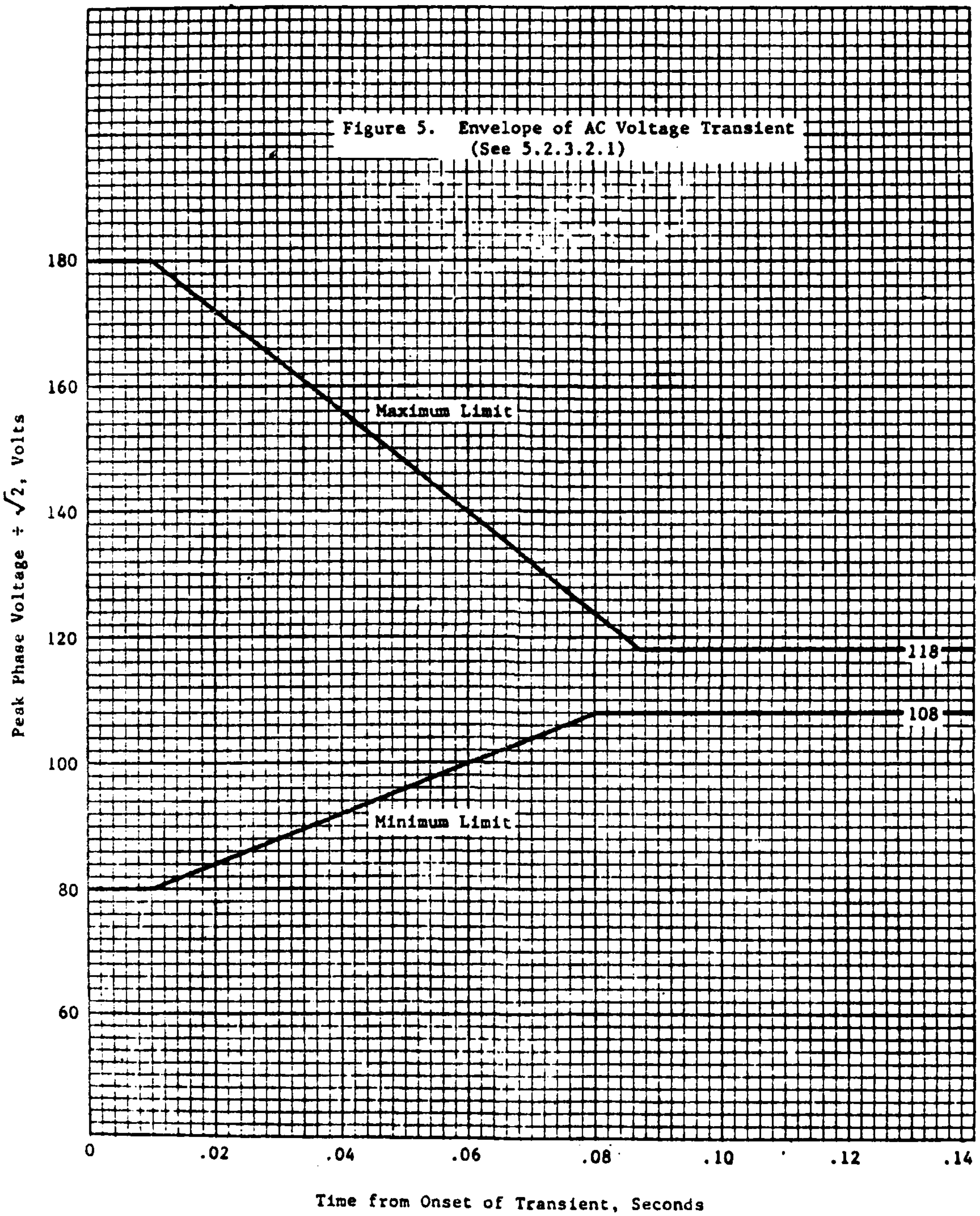


Figure 5. Envelope of AC Voltage Transient
(See 5.2.3.2.1)
180
160
140
120
100
80
60
Maximum Limit
Minimum Limit
118
108
0
.02
.04
.06
.08
.10
.12
.14
Peak Phase Voltage ÷ √2, Volts
Time from Onset of Transient, Seconds

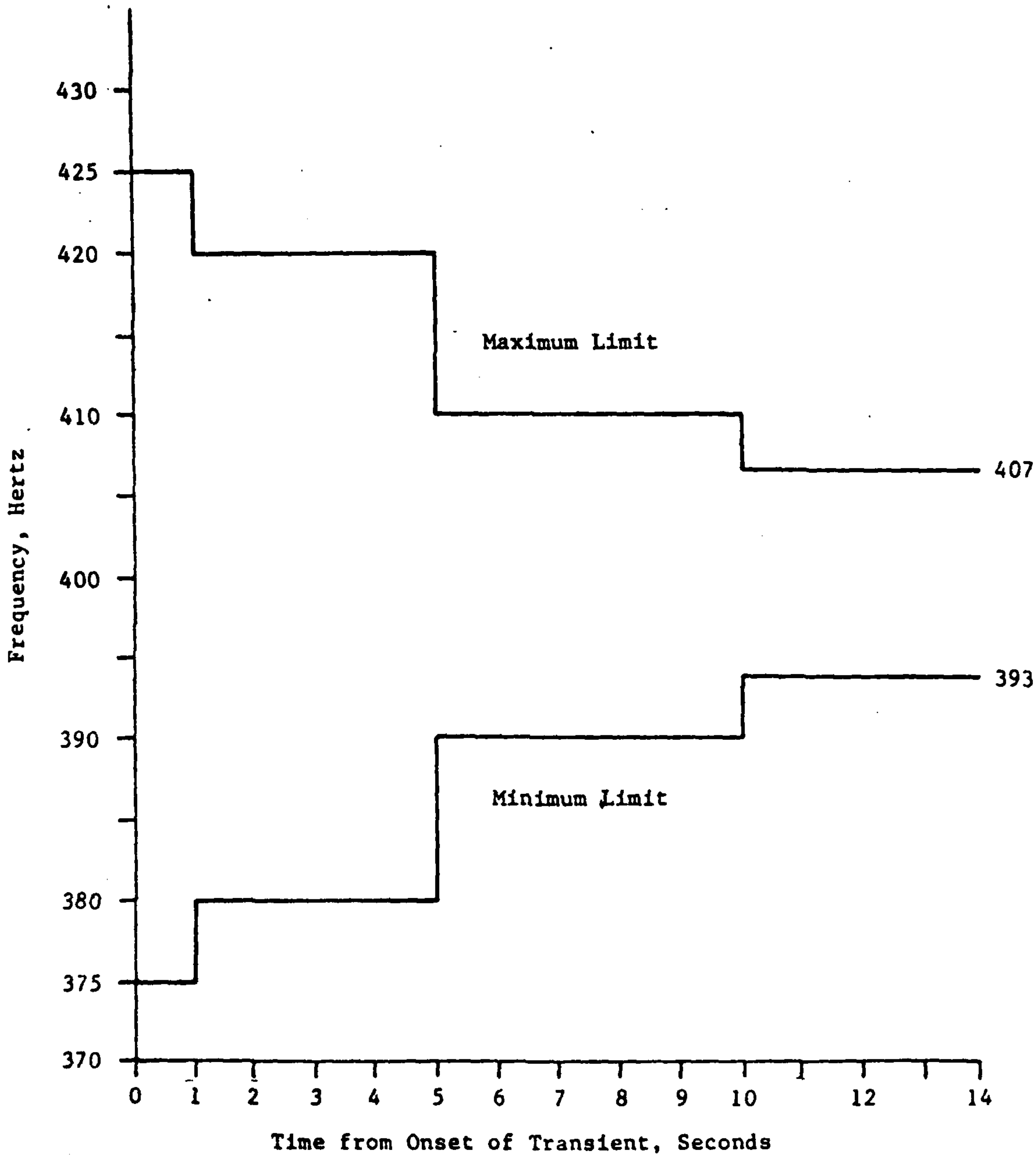


Figure 6. Envelope of AC Frequency Transient
(See 5.2.3.2.2.1)

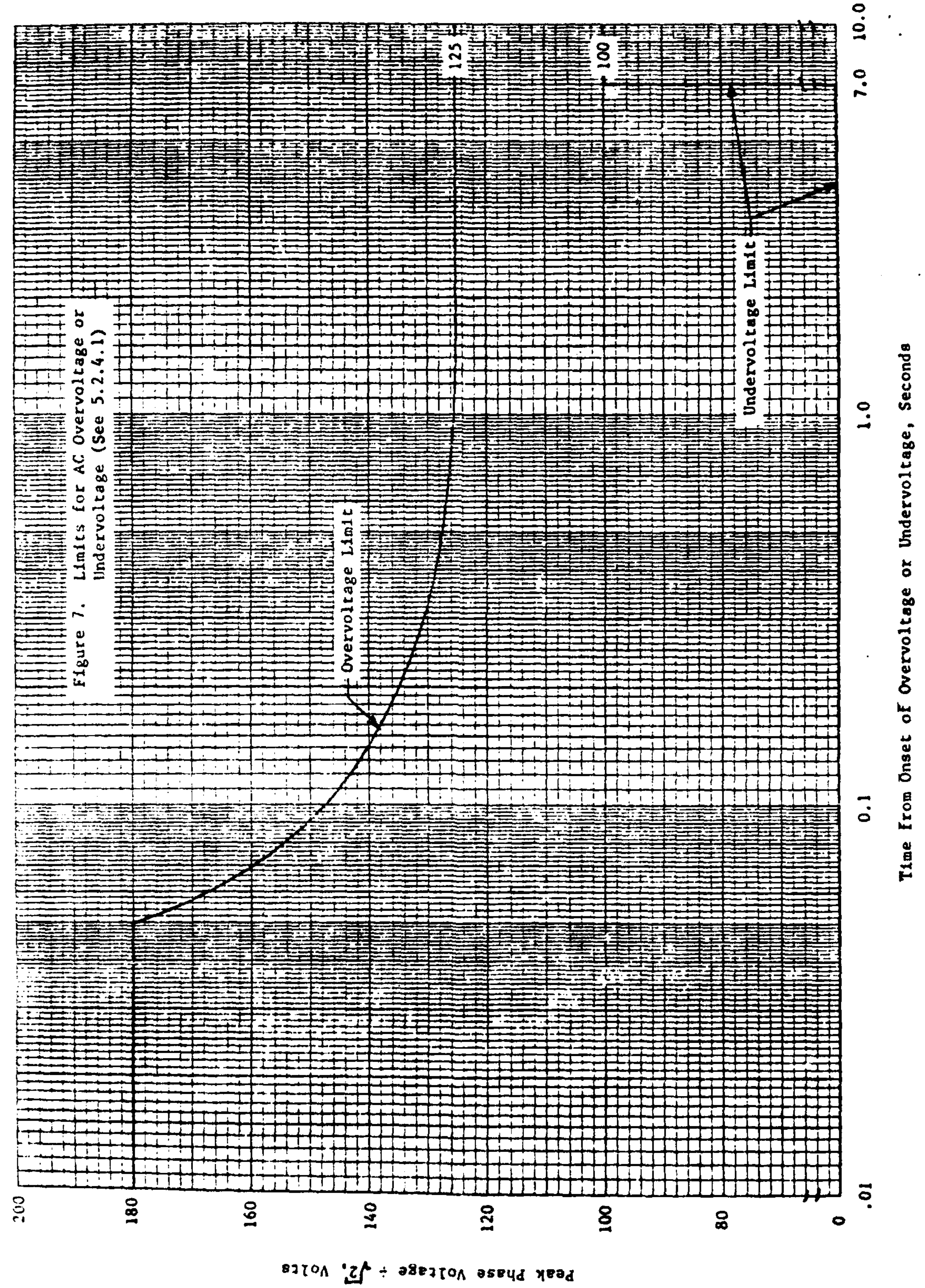


Figure 7. Limits for AC Overvoltage or Undervoltage (See 5.2.4.1)

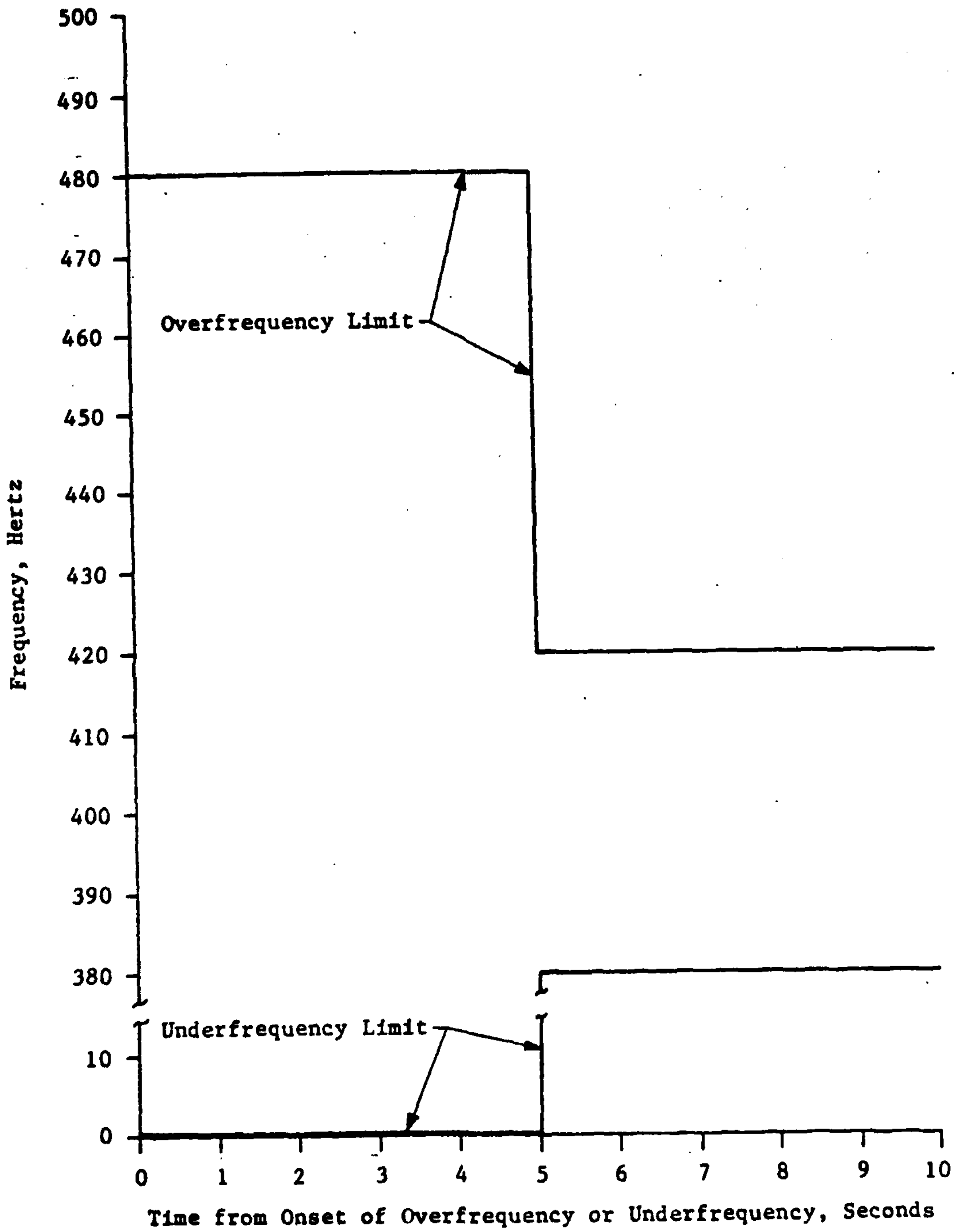


Figure 8. Limits for AC Overfrequency or Underfrequency (See 5.2.4.2)

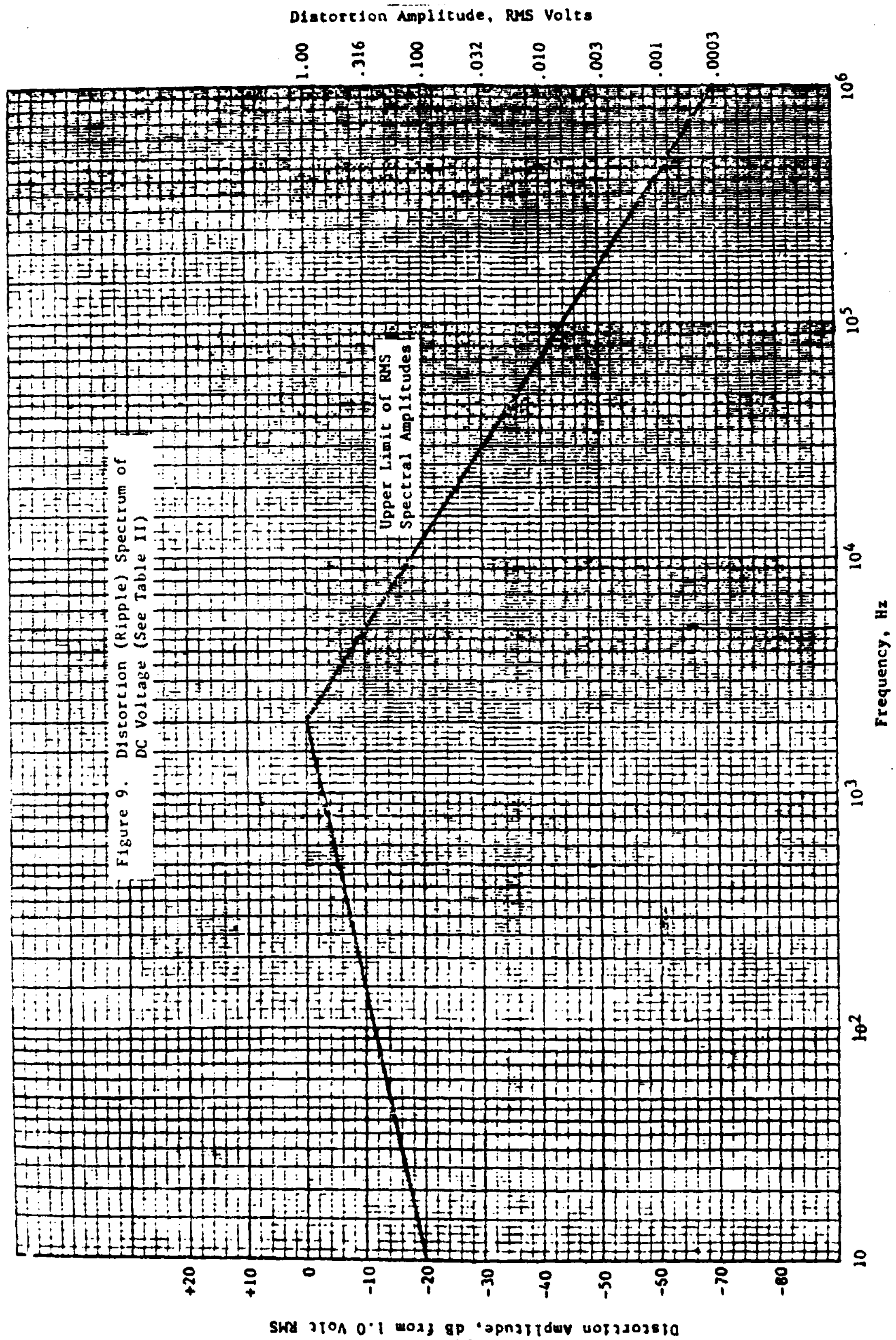


Figure 9. Distortion (Ripple) Spectrum of DC Voltage (See Table II)

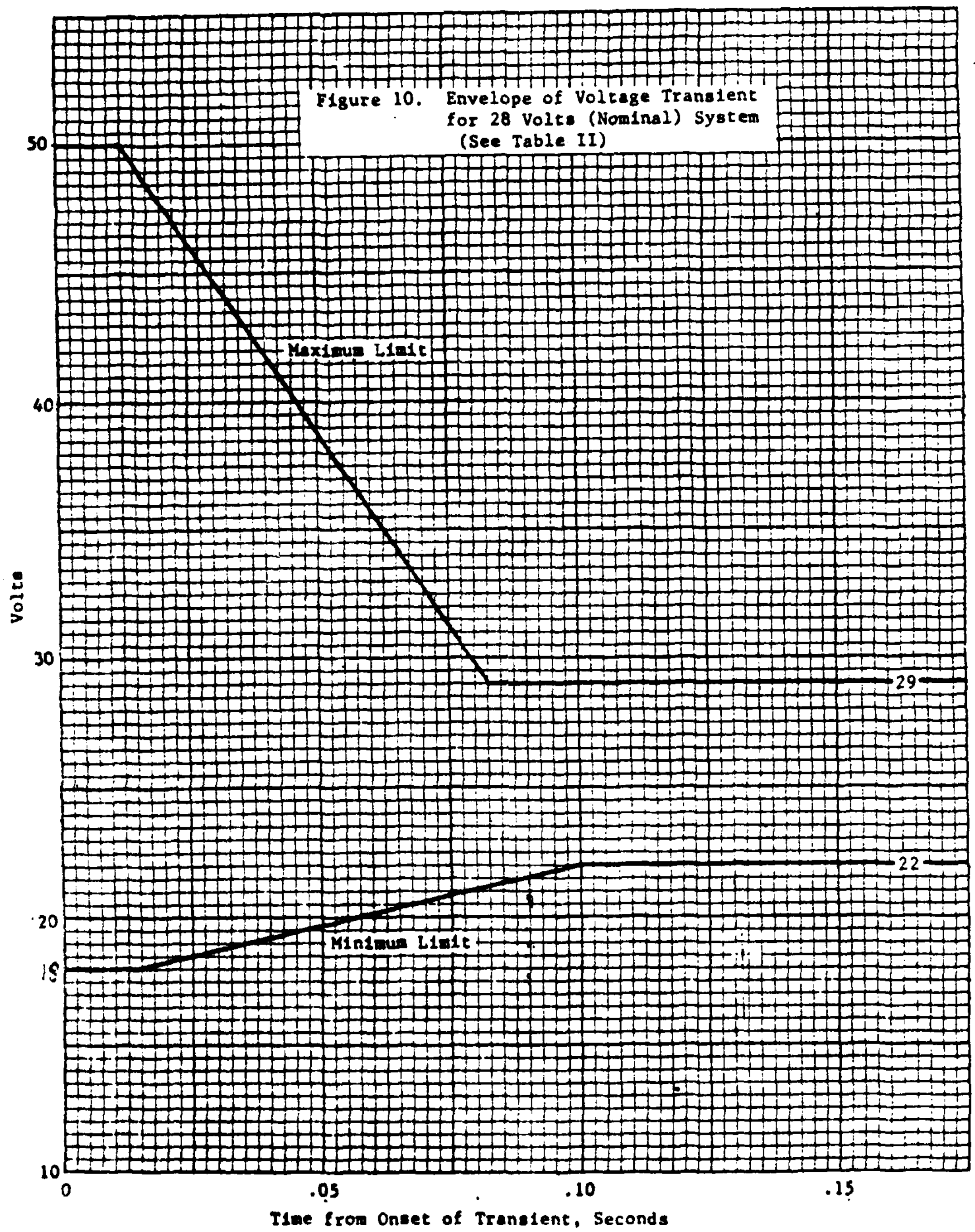


Figure 10. Envelope of Voltage Transient
for 28 Volts (Nominal) System
(See Table II)
Maximum Limit
Minimum Limit
29
22
50
40
30
20
18
10
Volts
0
.05
.10
.15
Time from Onset of Transient, Seconds

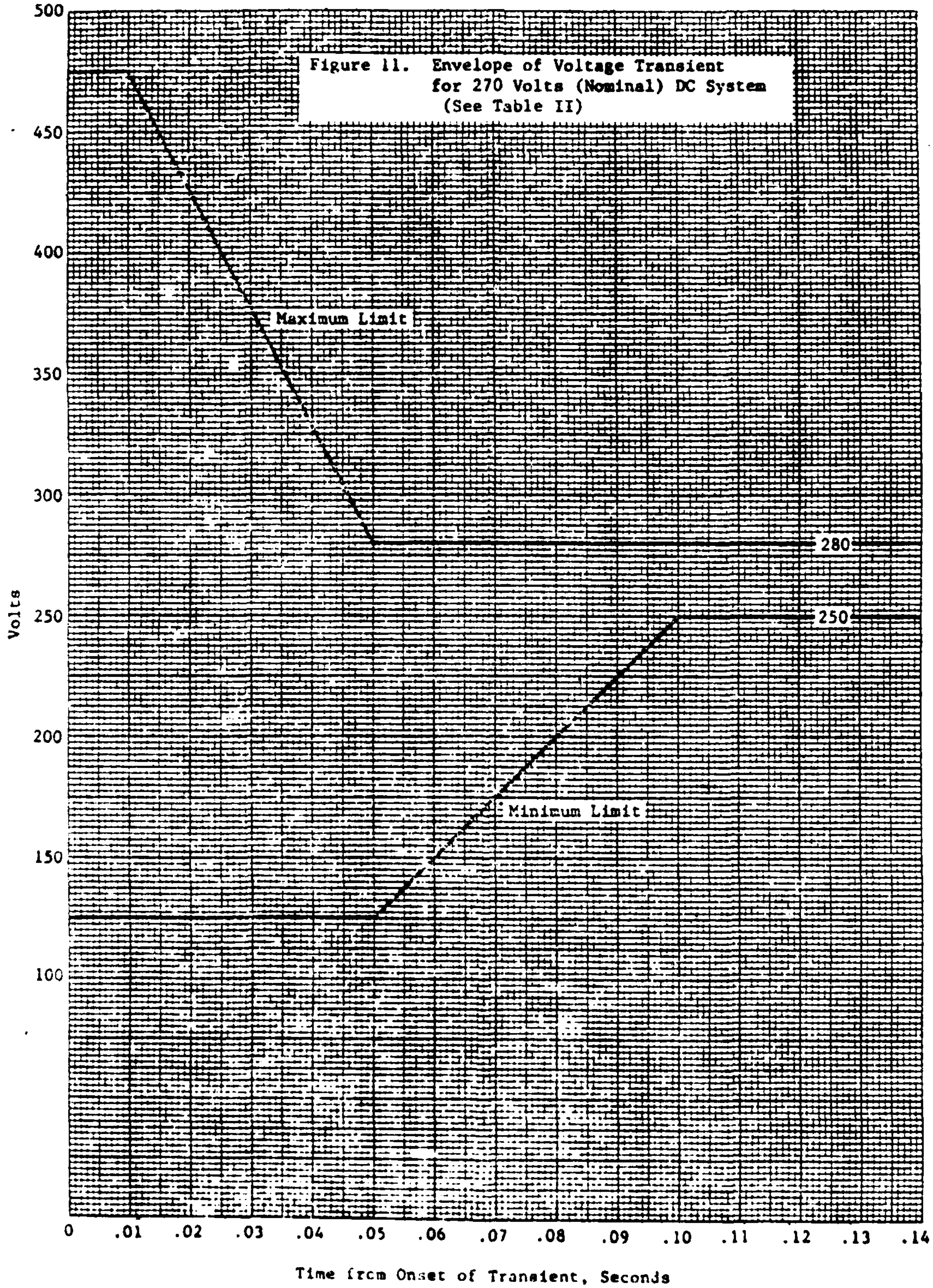


Figure 11. Envelope of Voltage Transient for 270 Volts (Nominal) DC System (See Table II)

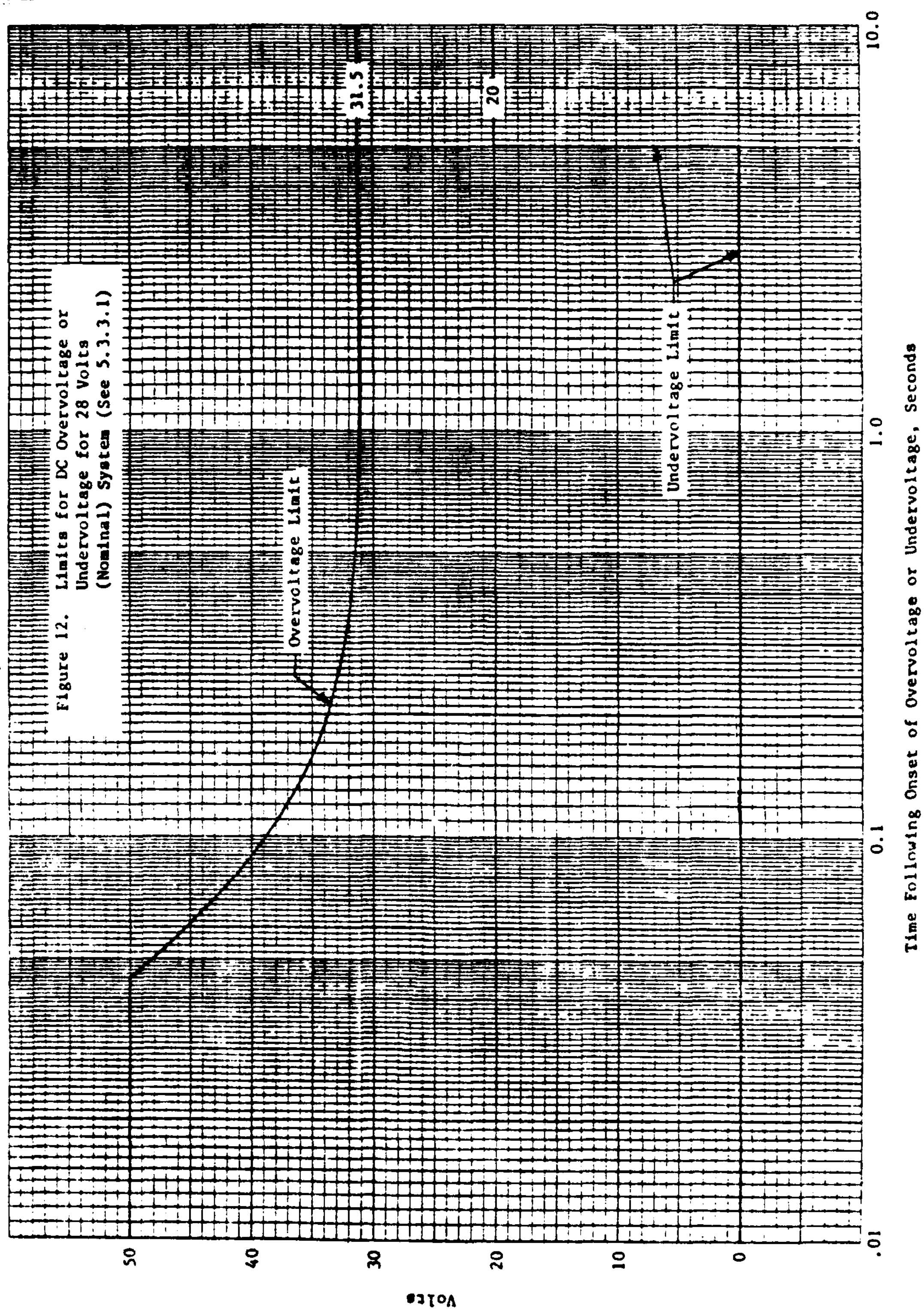


Figure 12. Limits for DC Overvoltage or Undervoltage for 28 Volts (Nominal) System (See 5.3.3.1)

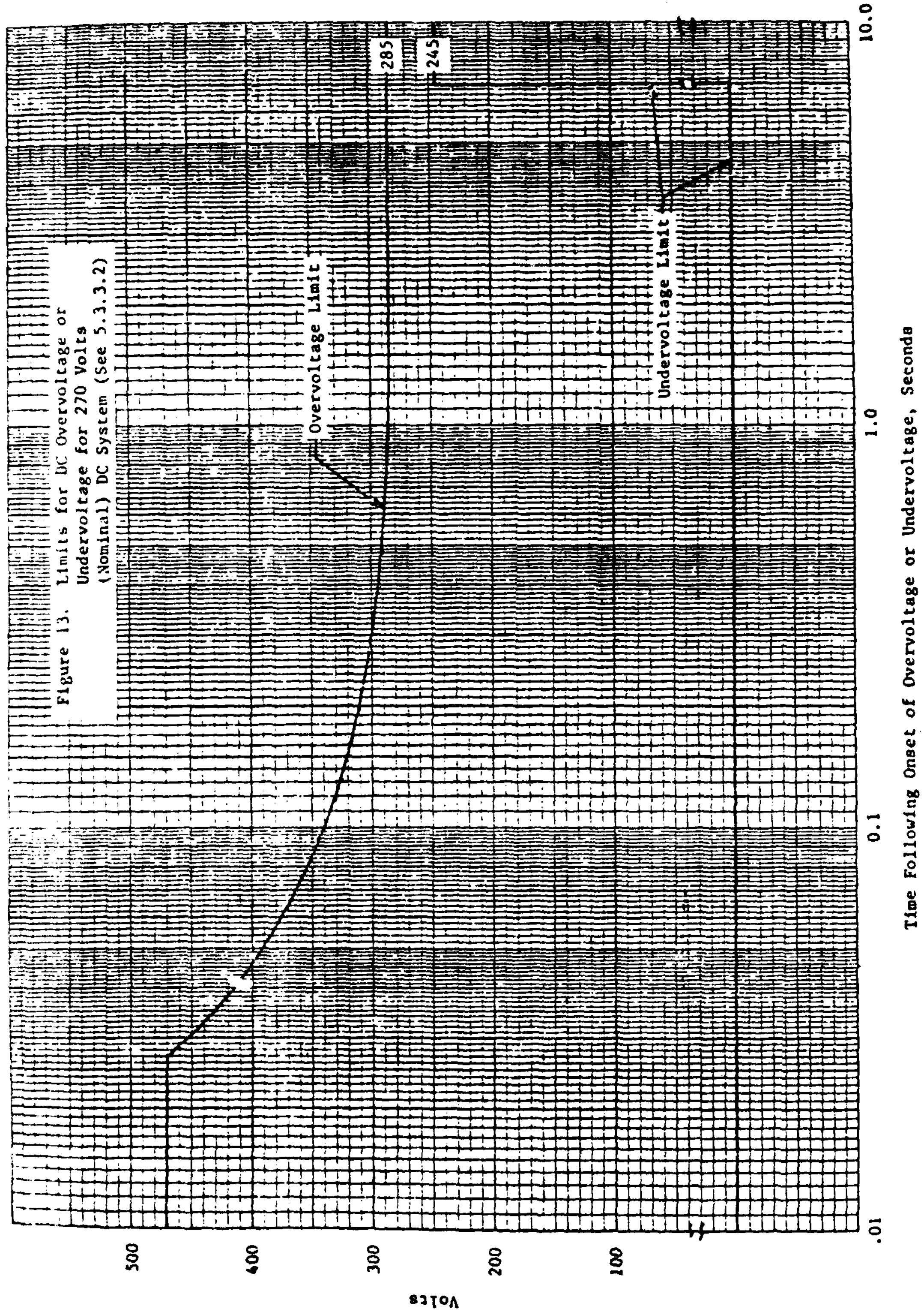


Figure 13. Limits for DC Overvoltage or Undervoltage for 270 Volts (Nominal) DC System (See 5.3.3.2)

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